



# **NASA's Contributions to Medicine**

## **An Investment in Society**

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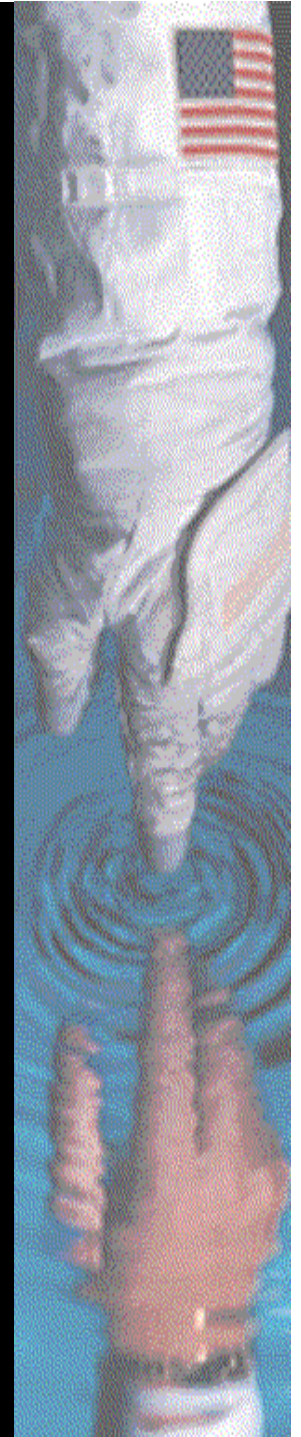
July 1999





## Outline

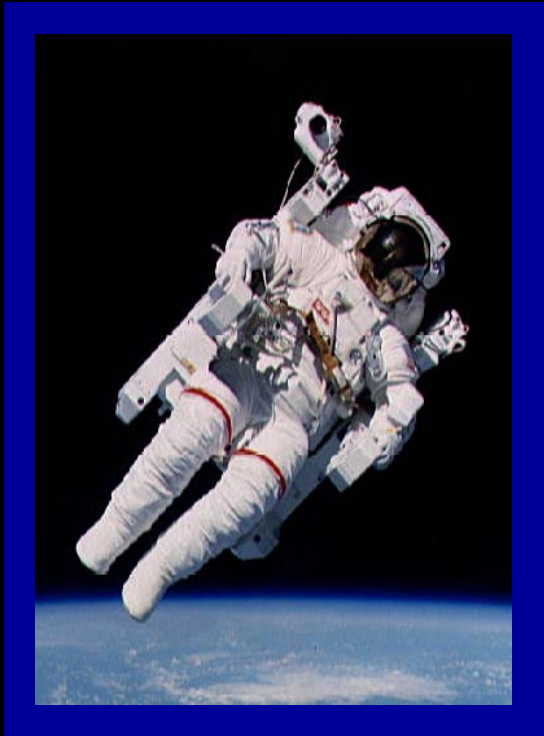
- Medical informatics
  - ✓ telepresence today
  - ✓ tomorrow's cyberpresence
- Biotechnology
  - ✓ protein crystallography
  - ✓ cell science
- Advanced medical systems
- Fundamental medical knowledge
  - ✓ Cardiovascular
  - ✓ Neurovestibular
  - ✓ Bone/muscle





## ***Medical Informatics...***

*... is the integration of  
research, medicine,  
engineering, and cybernetics  
disciplines*



*... incorporates the latest  
advances in information,  
miniaturization, and health  
care technology*





# Telepresence Today

*NASA harnesses the power of informatics to provide...*

- Telemonitoring
- Tele-education
- Telecare
- Telescience





# Telemonitoring & Telecare

## *Telemonitoring*

- Sensors
  - ✓ electronic nose
  - ✓ wrist actigraph
  - ✓ ingestible sensors
- Multimedia displays/controls
  - ✓ Wireless Augmented Reality Prototype



*Wrist actigraph*



*Telemedicine  
Instrumentation Pack*

## *Telecare*

- Specialist access & 2nd opinions
- Medical & surgical follow-up
- Transmission of diagnostic images
- Ground-based examples
  - ✓ STARPAHC
  - ✓ Spacebridge to Armenia
  - ✓ Ecuador surgery consult
  - ✓ Everest Extreme Expedition







# Telemonitoring

- Nutrition and metabolism
- Work-rest cycle





# Space Medicine Parameters

## *Adaptation*

- Cardiovascular/pulmonary
- Sensorimotor
- Endocrine
- Hematology

## *Pathophysiology*

- Bone and muscle strength loss
- Immune changes
- Radiation effects

- Human-machine interfaces
- Psychology/performance
- Habitability/resource utilization

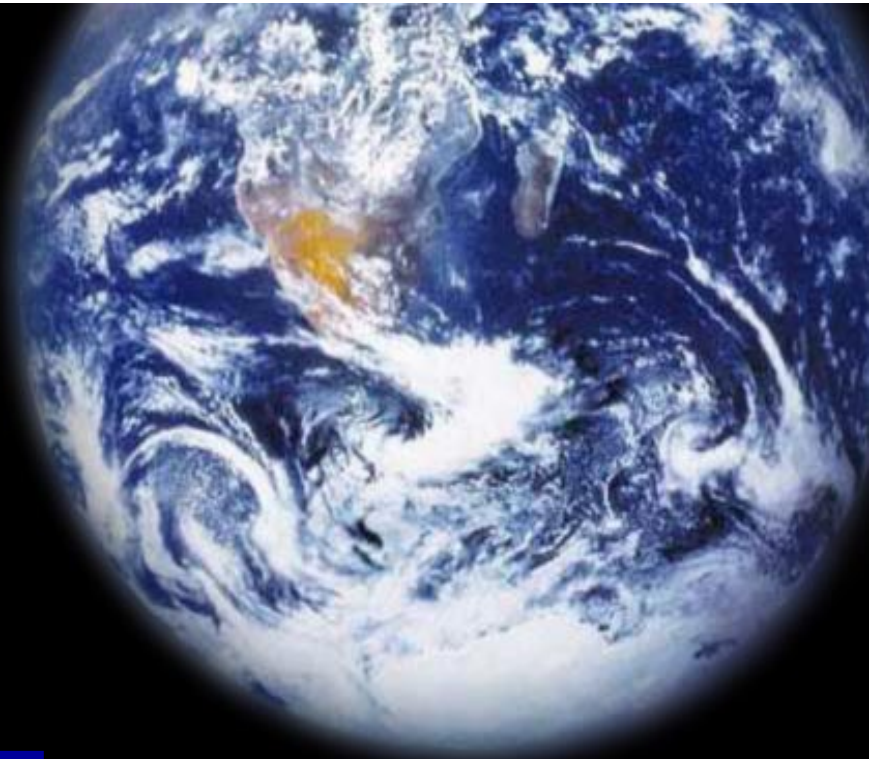




# Tele-education & Telescience

## *Tele-education*

- Student training
- Pre-surgery planning
- Continuing education



## *Telescience*

- Integration of flight & ground data
- Public health strategies
- Partners
  - ✓ NIH
  - ✓ CDC
  - ✓ World Bank



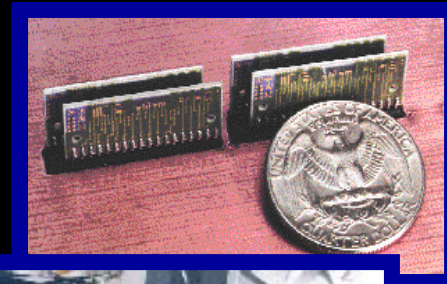




# NASA and Tele-science

NASA uses smaller, lighter technologies that permit less intrusive more efficient remote monitoring during missions.

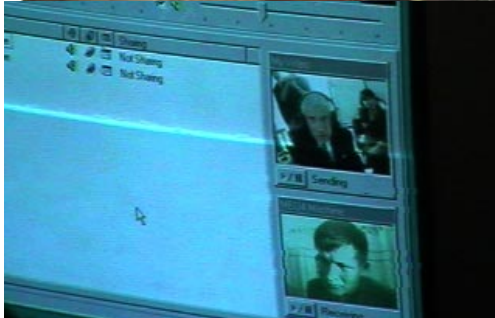
- NASA performs remote monitoring of astronaut health to:
  - ✓ Understand changes to the human body
  - ✓ Monitor vital signs
- NASA monitors the space craft environment for:
  - ✓ Impurities in the air
  - ✓ Radiation
  - ✓ Correct operation of space craft systems



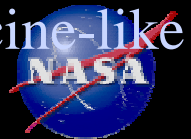


# NASA and Tele-education

NASA uses medical informatics technologies to advance tele-education.



- The **Space Bio-Medical Center for Training and Research** provides a virtual classroom on medical topics from the United States to Russian students, bridging cultural differences in medical care and training.
- The **East-West Space Science Center** brings Russian physicians and IT professionals to the United States to study telemedicine and distance learning technologies.
- The **Medical College of Virginia Commercial Space Center for Medical Informatics and Technology Applications** has developed a video streamed multi-media virtual lecture format that uses telemedicine-like technologies.





## NASA and Tele-care

NASA supplements on-orbit medical capabilities with telemedicine facilities.



- NASA has charted new uses for the World Wide Web as a telemedicine tool. The Space Bridge to Russia uses Internet technologies to simultaneously transmit data, images, video and voice -- eliminating distance as an obstacle to providing quality health care.
- The Telemedicine Instrumentation Pack (TIP) provides a wide array of medical diagnostic equipment to survey the health of the astronaut and communicate that data back to physicians on Earth.

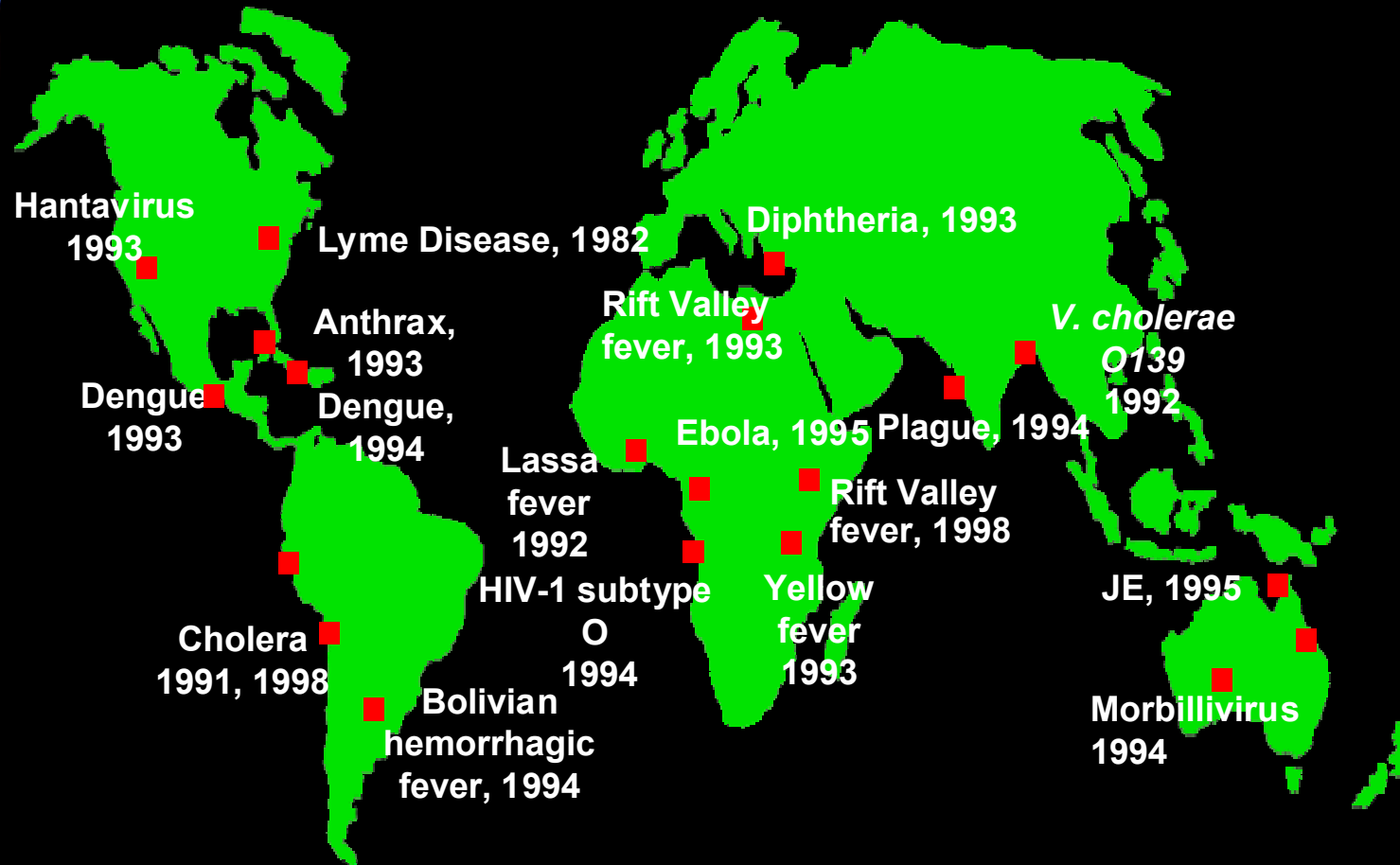


# NASA Telemedicine Links





# NASA Vector-Borne Disease Projects







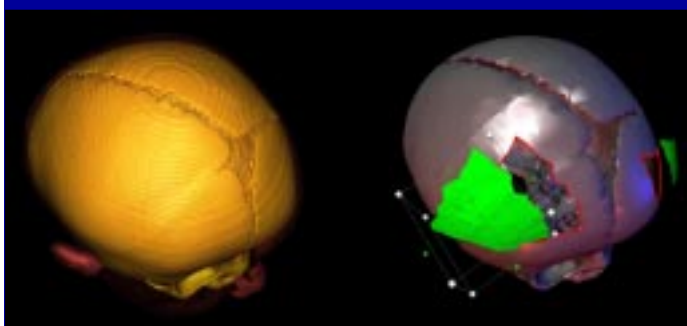
# Virtual Reality & Miniaturization

## *Virtual Reality*

- Improved skills
- Pre-surgery planning
- New techniques testing
- Immersive robotic surgery

## *Miniaturization*

- Imagery
  - ✓ x-ray
  - ✓ MRI
  - ✓ ultrasound
- Sensors, effectors, and transmitters
  - ✓ surgical instruments
  - ✓ analyzers





# Portability & Biologically-inspired Technologies



## *Portability*

- Sensors
  - ✓ “smart” T-shirts
  - ✓ “smart” suits
  - ✓ force interface
- Biochemical probes
- Immersive technologies



## *Biologically-inspired Technologies*

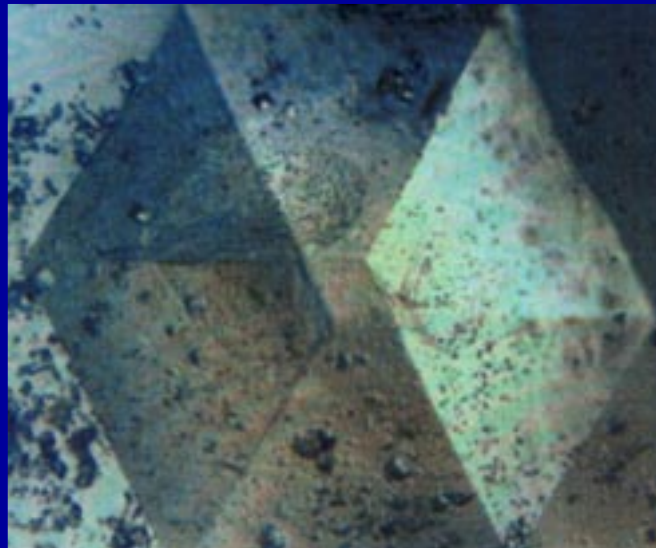
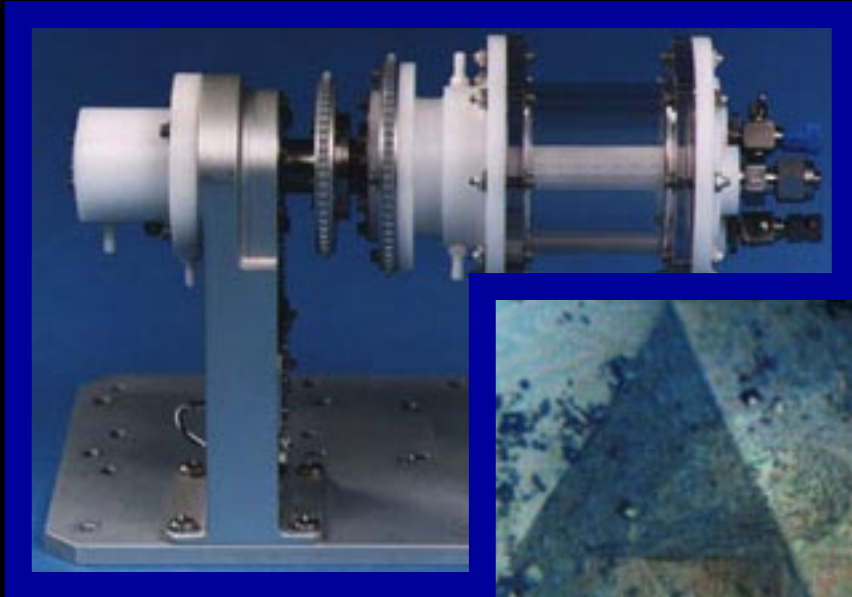
- Biological traits
  - ✓ Adaptive
  - ✓ Anticipatory
  - ✓ Collaborative
  - ✓ Curious
  - ✓ Guided motor control
  - ✓ Self-modeling
  - ✓ Self-repairing
- Biological materials





# ***Biotechnology...***

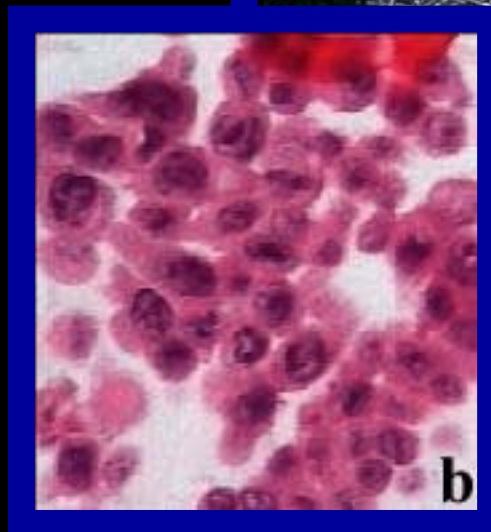
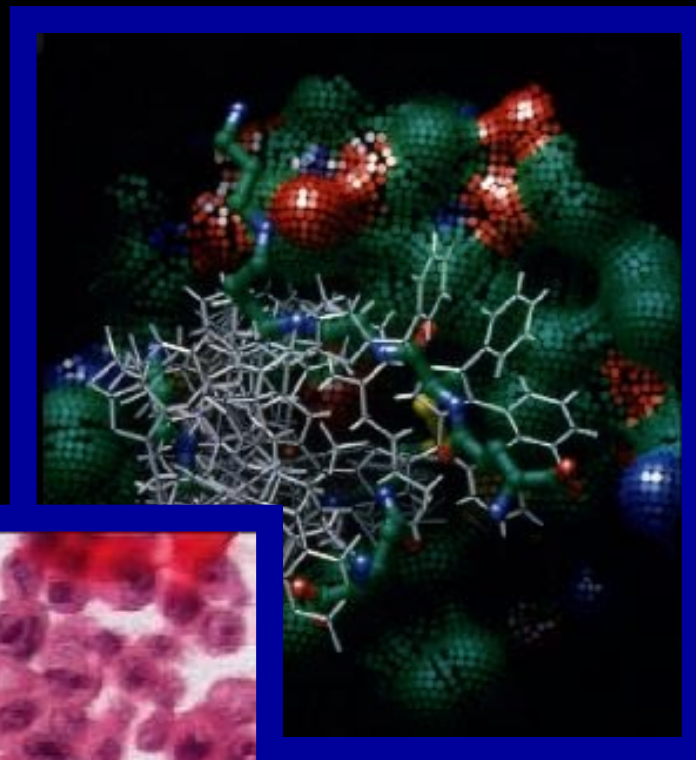
*...is the research,  
manipulation, and  
manufacturing of  
biological molecules,  
tissues, and living  
organisms.*





# NASA & Biotechnology

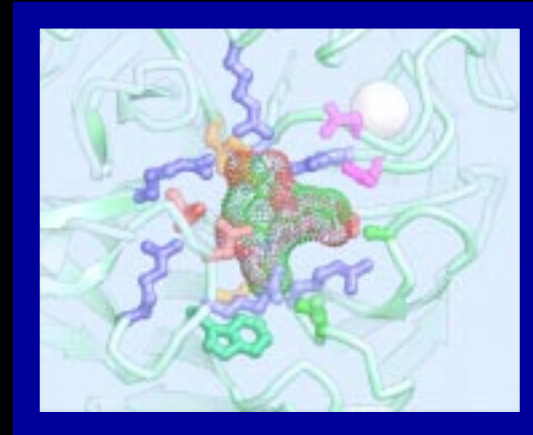
- Protein crystal growth
  - ✓ influenza
  - ✓ AIDS
  - ✓ diabetes
- Cell science
  - ✓ cartilage
  - ✓ colon cancer
  - ✓ breast cancer





# Protein Crystal Growth

- Select advantages of microgravity-grown protein crystals
- Recent advances in protein structure determination
- Current & past projects NASA CSC for Macromolecular Crystallography include work on proteins relevant to disease treatment of
  - ✓ influenza
  - ✓ diabetes
  - ✓ AIDS
  - ✓ psoriasis
  - ✓ contact dermatitis
  - ✓ T-cell lymphoma

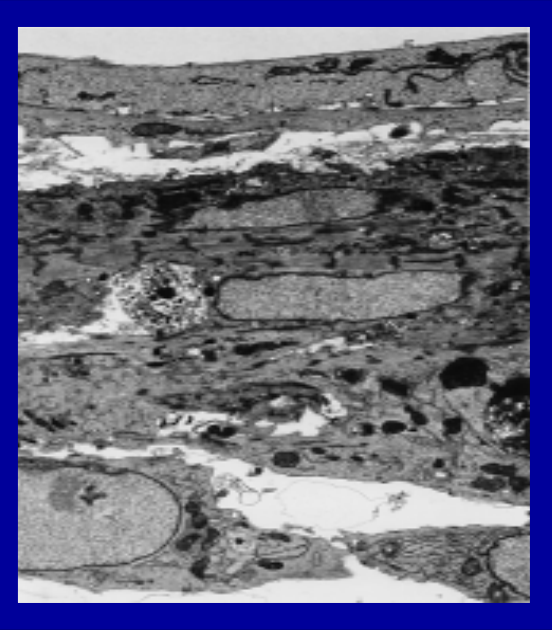






## Cell Science

- NASA-developed Bioreactor is now used to propagate a variety of tissues for disease research, including
  - ✓ cancers (colon, breast, ovarian, prostate, endocrine)
  - ✓ normal tissues for structural studies & pathogen research (cartilage, cardiac, liver, lymphoid, thyroid, skin, pancreatic islet cells, neuroendocrine cells, intestinal epithelium)



*cardiac muscle grown in  
the bioreactor*





# Cell Science

## Accomplishments

- More than 25 patents and disclosures
- Licensure to Synthecon, Inc. to manufacture the ground-based bioreactor
- Licensure to VivoRx, Inc. for the production of pancreatic islets cells for transplantation into patients with Type I diabetes.
- Space Act Agreement with VivoRx to use the bioreactor to promote the growth and differentiation of human cells for transplantation
- MOU with the Juvenile Diabetes Foundation
- Microencapsulation of chemotherapeutic drugs





# **Dried Blood Chemistry Device™**

Brings efficiency and innovation into daily medical practice worldwide

- Medical equipment flown aboard the Shuttle must
  - ✓ use limited power
  - ✓ take up minimal volume or stowage area
  - ✓ meet toxicity and offgassing requirements
- The Dried Blood Chemistry Device (DBCD™) uses the innovative approach of stabilizing medical samples for storage at room temperature
  - ✓ blood samples taken inflight are filtered through fiberglass paper material, and then dried on the same material
  - ✓ once dried, samples are stable at room temperature for months
  - ✓ once returned to the ground, samples can be rehydrated for analysis and testing





**DBCD™**

- Through a Space Act Agreement, NASA and DBCD, Inc. of Houston, Texas are partnering to bring simplified sample collection and analysis to astronaut crews and the medical community at large
- Medical facilities worldwide are interested in using the DBCD™:
  - ✓ compact size and easy operation
  - ✓ potential for *in situ* sample analysis
  - ✓ collect serum anywhere from any species





# Genesis of the Protective Suit

- Space suit technology was first developed to provide life support for astronauts on the surface of the Moon and in orbit
  - ✓ Protective fabrics and materials protect astronauts from
    - Solar rays
    - Temperature extremes
  - ✓ Distinguishing features of the suit
    - Portable
    - Closed-loop
    - Extended-duration
- One component, the Cool Suit, improves regulation of body temperature







# Cool Suit Applications

Permits individuals with genetic defects or diseases to live normal lives

- Battery-powered personal air-conditioning system (personalized for wearer)
- Cooled solution pumped through suit channels
- Eliminates 40-60% of personal body heat
- Improves heat tolerance in patients with
  - ✓ Multiple Sclerosis
  - ✓ Cystic Fibrosis
  - ✓ Severe burns
- Enhances industrial conditions
  - ✓ Small airplane/helicopter pilots
  - ✓ Firefighters
  - ✓ Select heavy industry applications





# Protective Suit Timeline

**May  
1997**

- Genesis of the protective suit concept at NASA JSC: 2 layers of UV protective garments and cooling vest (derived from previous NASA work with “Cool Suit”)

**Sept.  
1997**

- First prototype suits delivered to 2 brothers in England; NASA signs Space Act Agreement with the HED Foundation of Virginia to provide suits and gather monthly status reports

**May  
1998**

- Second prototype suit delivered to Virginia boy

The HED Foundation continues to donate suits worldwide (650 thus far), with 30 children are on the Foundation’s waiting list for suits





## Protective Suit Use

Unites advanced technology with the unique medical needs of thousands of children worldwide

- Polymorphic Light Reaction Syndrome
  - ✓ Experience severe skin reactions to any sort of Sun exposure
  - ✓ Without protective gear, can only venture out at night
- Hypohydrotic Ectodermal Dysplasia
  - ✓ Born without sweat glands in all or part of the body
  - ✓ Cannot regulate their body temperature
  - ✓ Can lead to severe ulcerating in the tissue, the need for limb amputation, and even death
- Additional rare genetic conditions can cause extreme sensitivity to UV rays or the inability to properly regulate body temperature





## Protective Suit Use

Increases the quality of life of multiple sclerosis sufferers

- 350,000 Americans suffer from multiple sclerosis (MS), a degenerative nerve condition\*
  - ✓ Twice as many women as men
  - ✓ Average age of onset between 30 and 50
- A portion of MS patients are extremely sensitive to heat, and experience
  - ✓ Extreme fatigue and decreased performance
  - ✓ Muscle spasms & weakening
  - ✓ Slurred speech
- A liquid-cooled garment alleviates symptoms, increasing the quality of life and productivity of MS patients



*\*Multiple Sclerosis Foundation*



## Protective Suit Impact

*“It's amazing to think  
that NASA  
astronauts walking  
on the Moon means a  
child can now play in  
the Sun.”*

- Sarah Moody, founder and president of the HED Foundation, which donates these “space suits” to children in need.



Kyle and Ryan Richards of Shotton Colliery, England







# Smart Probe

Advances diagnosis of breast cancer  
by integrating novel technologies

- **Silicon chips**
  - originally developed for use in the Hubble Space Telescope
  - adapted for integration into a fine needle-tip diagnostic tool
- **Neural net software**
  - provides visualization of cancerous tissues and prediction of metastasis
- **Robotic surgery “assistant”**





# Smart Probe

Enhances diagnostic capabilities

- **Computerized needle-like tool senses a lump in breast tissue**
  - Provides real-time detailed imaging of tissue
  - Avoids painful surgery or scarring
  - Requires half the time of traditional techniques
  - Limits exposure to X-rays
  - Reduces diagnostic costs by one-third
- **Diagnosis is provided in real-time**
  - Examines tissue features to determine if cancerous growths are present
  - Predicts the progression of the growth, and whether it will be an aggressive process



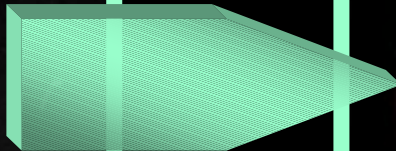
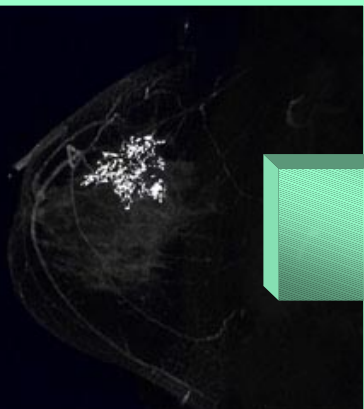


# Smart Probe

## Diagnostic Improvements

- Refinement of needle diagnostic technique will pave the way for diagnosis of other cancers, such as prostate and colon cancer
- RCS software will permit state-of-the-art digital imaging mammography
- Virtual reality technology will yield 3-D mammography images that can be viewed and manipulated by physicians

3D Image of  
breast  
performed  
with  
traditional  
techniques



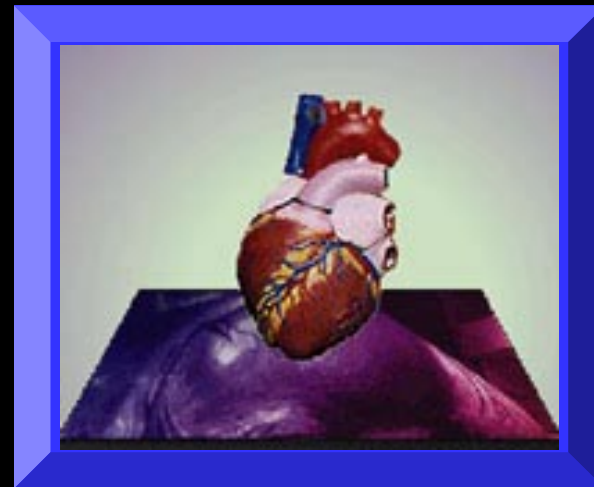
3D Image of  
breast performed  
with  
Reconstruction of  
Serial Sections  
(RCS)





## ***Fundamental Research...***

- Biomedical Studies and unique facilities
- Cardiovascular
- Neurovestibular
- Bone/muscle
- Immune system
- Cell science





# Current Efforts in Biomedical Research

- Astronaut Longitudinal Study (JSC)
  - ✓ Astronauts' physical and mental health parameters tracked from selection through retirement
  - ✓ Participation: 160 active astronauts, 123 retired astronauts, and 25 astronaut candidates
- Biocomputation & Cybersurgery (ARC)
- Pharmacology (limited)
- Ergonomic standards (limited)
- Minimal funds for work in medical or surgical practices in space







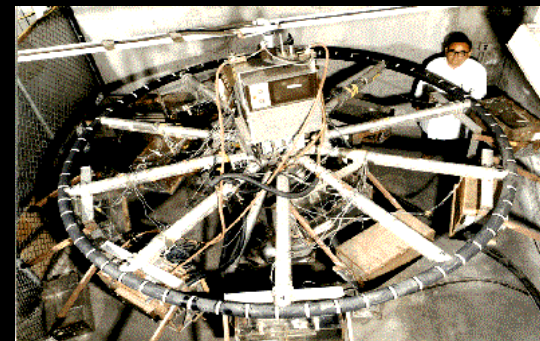
# Unique Ground-Based Facilities



*KC-135 Aircraft*



*Sub-orbital Rockets*



*Centrifuges*



*The Center for  
Bioinformatics  
(previously  
Biocomputation  
Center) at ARC and  
Stanford U*



*Drop Towers/Tubes*



*Radiation Research at  
Loma Linda Medical  
University*

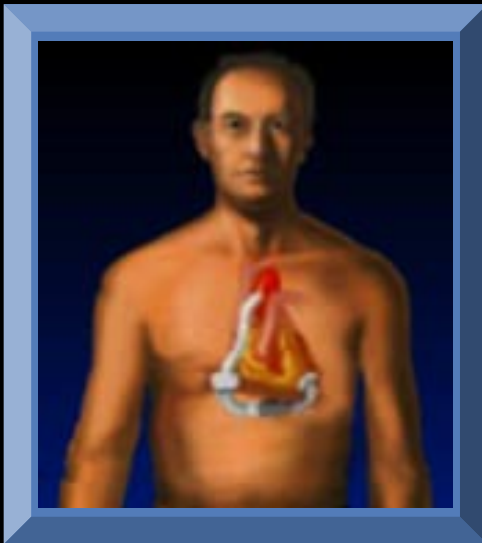


*Life Support Test Beds*

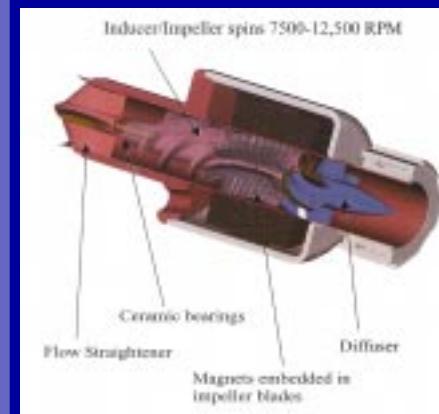
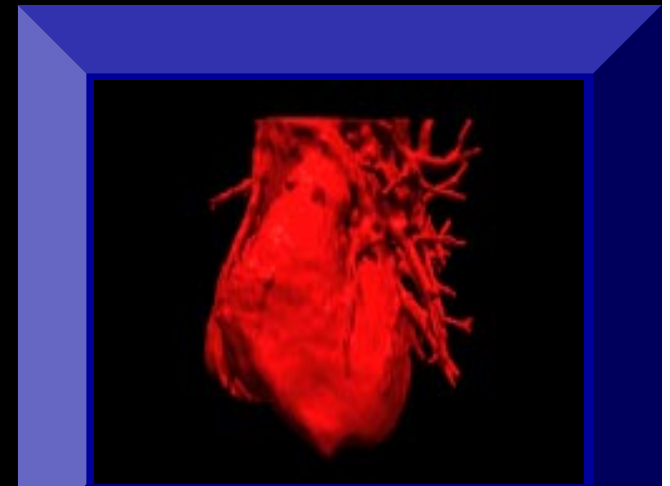


# Cardiovascular -- From Trends into Reality

- Ventricular Assist Device has several applications in medical and commercial situations as a low power, limited size device:



- ✓ one component of a compact Heart-Lung Machine
- ✓ allows for recovery of the natural heart
- ✓ serves as a bridge-to-transplant
- ✓ allows the patient to lead a normal and active life

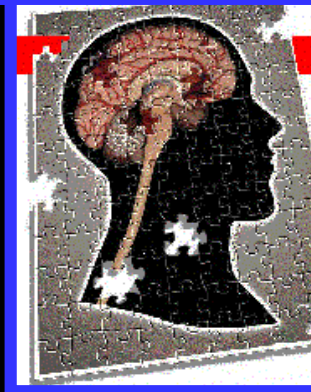
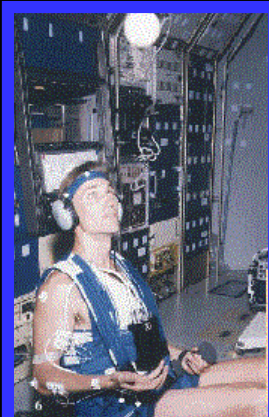




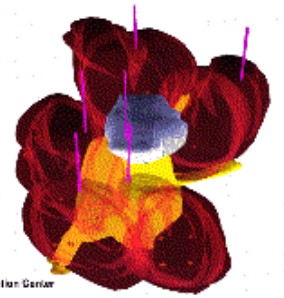
# Neurovestibular

## *Issues*

- Astronauts, seniors, and others affected by diseases experience changes in the neurosensory system
- 18% of people 65 - 75 years of age, suffer from problems with balance and gait
- Half of all falls that occur with the elderly are caused by vestibular dysfunction and result in 200,000 hip fractures a year



Otolith



## *NASA's Results*

- Robots who perform complex tasks
- Role of vision in spatial orientation
- Treatment for patients suffering from balance disorders
- Knowledge of neurological disorders associated with the cerebellar deficiency, basal ganglia, and parietal and frontal cortex (Parkinson's) disease



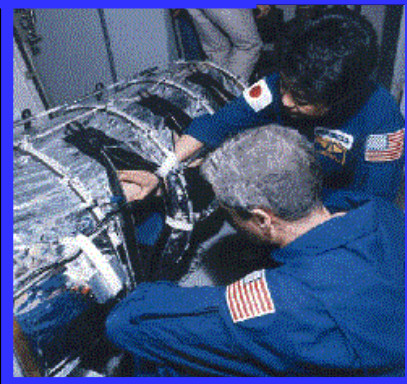
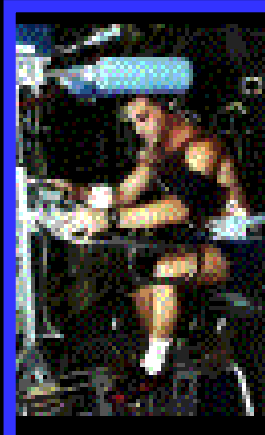




# Bone and Muscle

## *Issue*

- Several thousand Americans suffer from osteoporosis (1 in 2 women and 1 in 8 men have a lifetime risk of suffering an osteoporotic fracture).
- A woman's risk of hip fracture is equal to the combined risk of developing breast, uterine, and ovarian cancer.



## *NASA's Results*

- Decrease the recovery time from injury to athletes and senior citizens
- Insight into bone and muscle atrophy and osteoporosis
- Role of muscle loading for normal development of the motor system of premature infants





# Immune System

## *Issue*

- Most individuals are infected with viruses that normally are not active. If the immune system becomes compromised these viruses can activate
- As we age, our immune system also ages, leading to decreased immune function and increased vulnerability to infectious diseases



## *NASA's Results*

- Microgravity and the body's ability to fight infections
- The molecular basis for age-related immune changes
- A basis for designing interventions to alter or prevent changes in immune function







## Cell Science

The microgravity environment is a unique and valuable arena in which to study tissue culture and growth.

NASA's Rotating Wall Vessel (Bioreactor) exploits the utility of microgravity and advances clinical studies on Earth. It is now available for commercial use.



Results gleaned from several Shuttle and *Mir* studies reveal that many types of human cells can be cultured in space with great success. Most recently, synthetic implants have been grown aboard the Shuttle.





# Sleep

## *Issue*

- 66 million people (1/3 of the adult U.S. population) experience problems with sleep



## *NASA's Results*

- Management of insomnia in shift workers and elderly
- Improved management of causes of jet lag, insomnia and mental disorders such as winter depression
- Examine how different medications effect quality of sleep.

